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Seasonal and Spatial Influences on Rotifera Biodiversity in the Upper Sector of the Tigris River Passing Through Wasit Province, Southern Iraq

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This study investigates the biodiversity, diversity, and distribution of Rotifera in the upper sector of the Tigris River, Wasit Province, Iraq, from January to December 2022. Five sites, approximately 10 Km apart, were selected along a 1415 Km stretch of the river. A total of 67 rotifer taxa were identified. The highest density recorded was 27,454 individuals/m³ in November, and the lowest was 710.6 individuals/m³ in July. The relative abundance index identified five less abundant rotifer species. The species richness index ranged from moderate to ideal, while the Shannon-Wiener index indicated moderate diversity. The species uniformity index varied from unbalanced up to highly balanced. Sites 2 and 3 had the highest similarity index values, whereas sites 1 and 4 had the lowest. Thirty-four taxa were constant species, with others being accidental or accessory. Our results concluded that upstream areas recorded lower relative abundance compared to downstream. According to the Shannon-Wiener index, the Tigris River can be classified as having high diversity, suggesting a good and diversified aquatic ecosystem.
Keywords: Rotifera, Biodiversity, Tigris River, Wasit Province, Rotifera, Biodiversity, Diversity, Distribution, Tigris River, Wasit Province.

INTRODUCTION

In aquatic food webs, zooplankton play a crucial role in transferring energy from autotrophs to heterotrophs (Manickam *et al.* 2015). Freshwater zooplankton primarily consist of Rotifera, Cladocera, and Copepoda (Ahmed and Ghazi, 2014). Rotifera, acoelomate microscopic invertebrates, are essential in aquatic ecosystems for their role in transferring energy from primary producers like bacteria and algae to consumers such as crustaceans, insects, and small fish (Solanki *et al.*, 2015). Rotifera exhibit significant morphological diversity and adapt to various environmental conditions (Joseph and Yamakanamardi, 2016).

Numerous regional studies have focused on zooplankton, including rotifers, such as those by Al-Lami *et al.* (2004); Radi *et al.*(2005);Nashaat, (2010); Nashaat *et al.* (2013); Hassan *et al.* (2014); Ala Allah *et al.* (2015); Nashaat *et al.* (2015); Nashaat *et al.* (2016); Rasheed *et al.* (2016); Abbas *et al.* (2017); Merhoon *et al.* (2017); Abed and Nashaat, (2018); Al-Bahathy and Nashaat, (2021); Nashaat *et al.* (2021); Majeed *et al.* (2021); Majeed *et al.* (2022a); Majeed *et al.* (2022b); Nashaat and Al-Bahathy, (2022); Abed *et al.* (2022); Al-Safi *et al.* (2022); Majeed *et al.* (2023a); Majeed *et al.* (2023b) and others. This study aims to provide a comprehensive description of the temporal and spatial effects on rotifer biodiversity in the upper sector of the Tigris River passing through Wasit Province.

MATERIALS AND METHODS

***Description of the study's area*:** The study was conducting on upper sector of Tigris River, in Wasit Province. Sampling was carried out from January to December 2022. Five sites, each about ±10 Km apart, were selected, divided along 1415 Km of the river (Figure 1). Suwayra District was the first site, about 135 Km far from north of Kut City, and it is approximately 55 Km south of Baghdad City, at 3649841.938 N and 480129.668 E. The second site was located in Hafria District, about 110 Km far from north of Kut City and 60 Km south of Baghdad, at 3648752.026 N and 485518.798 E. The third site was located in Azizia District, about 85 Km far from south of Baghdad and about 90 Km far from north of Kut, at 3640797.777 N and 504988.921 E. The fourth site was located in Numaniyah District, about 45 Km far from north of the Kut City, and 193.7 Km far from south of Baghdad, at 3604272.479N and 539294.603E. Finally, the fifth site was

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located north of the Kut Barrage, at 3598020.410N and 575265.550E.

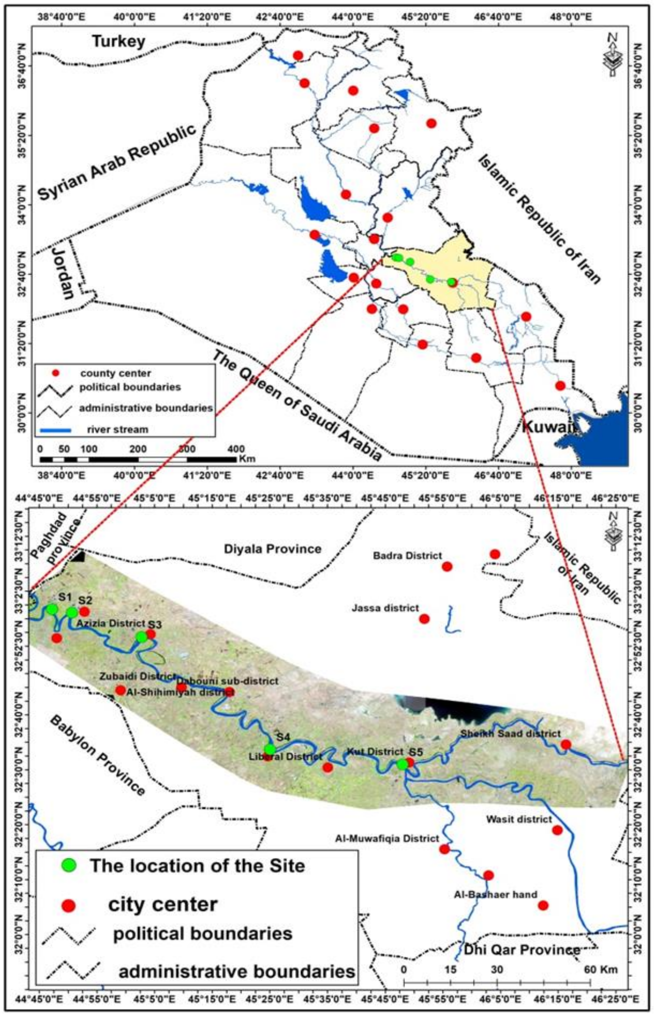

Figure 1. A map showing the study sites on upper sector of Tigris River within Wasit Province.

***Collection and Identification of Rotifera*:** From January to December 2022, samples were taken every month at a depth of 0.5 m. By using a 20 L graduated bucket and rotifer net with a mesh size of 55 m, 45 liters were filtered. In order to conserve the rotifer specimens, the samples were later concentrated to 10 ml in a cylindrical rotifer net container (Spellman, 2020). The species were identified by using the diagnostic keys that were readily available including: Edmondson, (1959); Pontin, (1978); Smith, (2001), and Hammadi *et al.* (2012), and the outcomes were expressed as individual/m^3.

Measures of diversity: The following ecological indicators have been accountable**:** Relative Abundance Index (Ra): This was determined using the formula presented by Odum, (1971) Ra% = (N÷Ns)*100 where N: a number of individuals at each taxonomic unit; Ns: the total number in the sample. Species Richness Index (D) was determined monthly by using Margalefe, (1968) formula D = (S-1)÷log N where S: species no.; N: total numbers of individuals. Jaccard presence – community**:** According to the Jaccard's, (1908) formula ISj= [C÷(A+B-C)] where *A* = no. of species on site A. *B* = no. of species on site B and *C* = no. of species in both of A and B sites. Shannon–Weiner Diversity Index (H) was determined monthly by using Shannon-Weiner's, (1949) formula. H=∑(ni÷n)*Ln (ni÷n) where ni: individuals no. per taxonomic unit; n: the total summation of individuals. A bit./Ind. unit expressed the results. Species Uniformity Index (E) was calculated using Neves *et al.* (2003) formula. E = H÷LnS where LnS: the greatest theoretical value is diversity; H: Value of Shannon-Weiner; S: number of taxonomic units at each site. Pielou, (1977) stated that if the index value were more than 0.5, uniformity would be apparent. Constancy Index (S): was determined according to Serafim et al. (2003) formula S = (n÷N)*100 where n = positive sample no.; N = total sample no..

RESULTS AND DISCUSSION

According to our findings, the rotifera density fluctuated spatially and temporally (Fig. 2). With regard to spatial variation, site 4 recorded the lowest value, which averaged 710.6 Ind./m^3, while Site 1 recorded the highest value, which equaled 27454 Ind./m^3. The lower density of rotifera may be due to the higher levels of salinity (Yuan *et al.* 2020) because they observed that salinity causes a drop in rotifera density. The high densities of rotifera in site1 may be various factors that support rotifera growth, including high percent oxygen saturation values (Bolawe *et al.* 2018). As for the temporal variations, the highest densities were recorded in summer and autumn, and this can be as a result of the increase in phytoplankton density, as the quantity of diatoms in the rivers causes the density of rotifera increasing due to their nutrient-relationships among them as well as the a suitable environmental conditions for both of them (Sharma *et al.* 2010). As for the lower density of rotifera in the spring and winter season, may be due to the presence of fish and aquatic invertebrates that prey on them (Al-Shamma'a *et al.* 2010).

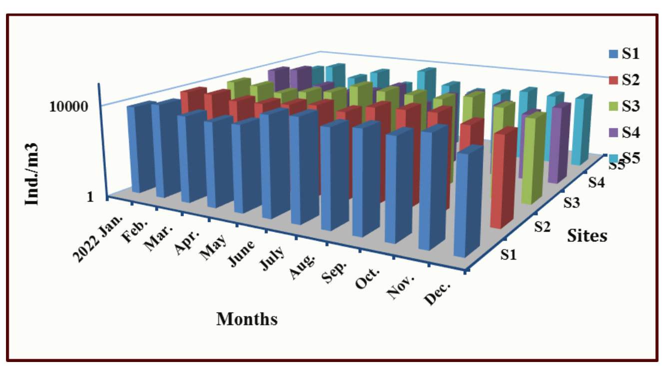

Figure 2. Monthly fluctuation of the total rotifera densities.

The relative abundance index showed presence of five less abundant species, including the following ones: *Brachionus*

Table 1. Indexes of relative abundance (Ra) and constancy (S).

	Ra%					S%				
Rotirera Site	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Argonothlca foliacea	-	-	+	+	-	-	-	+	+	-
*Anuroaeopsis fissa*Gosse, 1851	+	+	+	+	+	+++	+++	++	++	+
Aspelta bidentata (Wulfert, 1961)	+	+	+	+	+	+	+	+	++	-
*Asplanecna priodonta*Gosse, 1850	+	+	+	+	+	+++	+++	+++	+++	+++
Brachionus angularis Gosse, 1851	++	++	++	+	+	+++	+++	+++	+++	+++
B.bidentatus Anderson, 1889	+	+	+	-	+	+	++	++	+	+
*B.calcyflorus calcyflorus*Pallas, 1766	+	+	+	+	+	+++	+++		+++	+++
B.calcyflorus amphecerus(long spin)Pallas,1766	+	+	+	+	+	+++	+++	+++	+	+
B.calcyflorus amphecerus (short spin)Pallas,1766	+	+	+	+	+	+++	+++	+++	+++	+++
B.havanaensis Rousselet, 1913	+	+	+	+	-	+++	++	+++	+	-
Brachionus falcatus Zacharias, 1898	+	+	+	+	+	+++	+++	+++	++	++
B.forficula Pallas, 1766	+	+	+	+	+	++	+++	++	++	+
B.quadridentatus Hermann,1783	+	+	+	+	+	+++	+++	+++	++	++
B.quadridentatus(long spin) Hermann,1783	+	+	+	+	-	+	+	+	+	-
B.quadridentatus(short spin)Hermann,1783	+	+	+	+	+	++	+	++	+	+
B.leydigi	+	-	-	-	-	+	-	-	-	-
B.plicatlus Müller,1786	+	-	+	+	+	+++	+++	+++	+++	+
Brachionus urceolaris Müller,1773	+	+	+	+	+	+++	+++	+++	+++	+++
Brachionus sp.	+	+	-	-	-	+++	+	-	-	-
Dipleuchlanis propalula(Gosse, 1886)	+	-	+	-	-	+	-	+	-	-
Cephalodella aureculata(Wulfert, 1938)	+	-	+	+	+	+	-	+	+	+++
C.exigua (Wulfert, 1938)	-	-	-	-	+	-	-	-	-	+
Cephalodella gibba(Ehrenberg,1830)	+	+	+	+	+	+++	+++	+	+++	+++
Colurella adriatica(Ehrenberg,1831)	+	+	+	+	+	+++	+++	+++	++	++
Epiphanus macroura	+	+	+	+	+	++	+++	+++	+	+
Euchlanis delatata Ehrenberg, 1832	+	+	+	+	++	+++	+++	+++	+++	+++
Fillina longisetea Ehrenberg, 1834	+	+	+	+	+	+++	+++	+++	++	++
F. opliensis	+	+	+	+	+	++	++	++	+	+
Hexarethra mera Hudson,1871	+	+	+	+	-	++	++	+	-	-
Keratella cochlearis(Gosse,1851)	+	+	+	-	+	+++	+++	+++	++	+++
K.tropica(Apstein,1907)	+	+	+	+	+	+++	+++	+++	+++	+++
K.quadrata(Müller,1786)	+	-	+	-	-	+	-	+	-	-
K.quadrata(logn spin)Müller, 1781	+	+	+	++	+	+++	+++	+++	+++	+++
K.quadrata(short spin)Müller,1781	+	+	+	+	+	+++	+++	+++	++	+
K. valga Ehrenberg, 1834	+	+	+	+	+	+++	+++	+++	+++	+++
Lecan elasma Harring & Myers, 1926	+	-	+	-	-	+	-	+	-	-
L. luna (Müller, 1776)	+	+	+	+	+	+++	++	++	++	+
L.ohioensis Myers, 1926	+	-	+	+	+	+	-	+	+	+
L.tenuiseta	-	-	-	-	+	-	-	-	-	+
Lepadella ovallus	+	+	+	-	+	+	+	+	-	++
Manfridum.eudactylotum Remane, 1929	-	+	-	-	-	-	+	-	-	-
Monostyla bulla (Hauer, 1952)	+	+	+	+	++	+++	+++	+++	+++	+++
Monostyla closterocerca(Edmondson, 1935)	+	+	+	+	+	+	++	+	+	++
Monostyla hamata Stokes,1896	+	-	+	+	+	+	-	+	+	+
Monostyla lunaris (Harring and Myers,1922)	+	+	-	+	+	+	+	-	+	+
M.stenroosi (Meissner, 1908)	+	-	+	-	-	+	-	+	-	-
M. thionemanni	-	-	+	-	-	-	-	+	-	-
Monostyla quadridentata (Harring and Myers,1922)	-	+	+	+	+	-	+	+	+	+
M.thalera	-	-	+	+	+	-	-	+	+	+
Mytilina mucronata (Wulfert, 1939)	+	+	+	+	+	++	+	+	+	+++
Notholca acuminata	+	+	+	+	-	+	-	+	+	+
Notholca squamula (Ehrenberg,1832)	+	+	+	+	+	+	++	+	+	+
Notholca sp.	-	-	-	-	+	-	-	-	-	+
Platyias quadricornis (Ehrenberg,1832)	+	+	-	+	+	-	+	+	+	+
P.patulus (Müller,1786)	+	+	+	+	+	++	+++	++	+	+
Polyarthra dolicoptera(Idelson, 1925)	+	+	+	+	+	+++	+++	+++	+++	++
Pomopholyx sulcate(Gosse,1851)	+	+	+	+	-	+	+	+	+	-
P.vulgaris(Carlin,1943)	+	+	+	+	+	+++	+++	+++	+	+
Rotaria citrinus (Weber,1923)	+	+	+	-	+	+	++	++	-	+
R.neplunia Ehreberg,1830	++	++	++	++	++	+++	+++	+++	+++	+++
Stephanoceros fimbriatus (Larva) Berzins, 1951	+	+	+	+	+	++	++	+++	+	+
Syncheta oblonga Ehrenberg,1831	+	+	+	+	+	+++	+	+++	++	+++
Trichocerca bicristata (Wulfert,1956)	+	+	+	+	+	+	+	+	+	++
Trichocerca similis	-	-	-	-	+	-	-	-	-	+
Trichotria tetractis (Ehrenberg,1830)	+	+	+	+	+	++	+	+	+	+
Testudinella patina(Hermann,1783)	+	+	+	+	+	++	+++	++	+	+
T.rousseleti(Voigt,1901)	+	+	+	+	-	+	++	+	+	-

*In accordance with the Relative Abundance Index, where (+) denotes rare species (10% ≤), (++) denotes less abundant species (40%) -10%, (+++) denotes abundant species (70%) -40%, and D denotes dominant species (≤70%).The Constancy Index identifies the following species: (+) =Accidental species, present in a percentage of 1% to 25% in samples, (++)= Accessory species, present in a percentage of 25% to 50% in samples, and C=Constant species, present in a percentage ≤50% in samples.

angularis, *Euchlanis delatata K.quadrata*(logn spin), *Monostyle bulla* and *Rotaria neplunia* (Table 1).

Site 1 revealed that *R. neplunia* was present at the highest rate of 24% when compared to the overall density of other species in this site, then comes *B. angularis* 20%, *B. urceolaris* 6%, and each of *B. calcyflorus calcyflorus*, *K. quadrata* and *K. valga* with a rate of 5% (Fig. 3).

In regard to site 2, *R. neplunia* had the highest proportion (26%), when compared to the overall density of other species in this site, followed by *B. angularis* with 15%, then *K. valga* with 7%, and *K. quadrata* (Long spin) with 6%.

Site 3 revealed the existence of *R. neplunia*, which accounted for the highest proportion (22%) of the total species density there, followed by *B.angulaeis* (15%), *B.calcyflorus* (9%), and *K.valga* (8%).

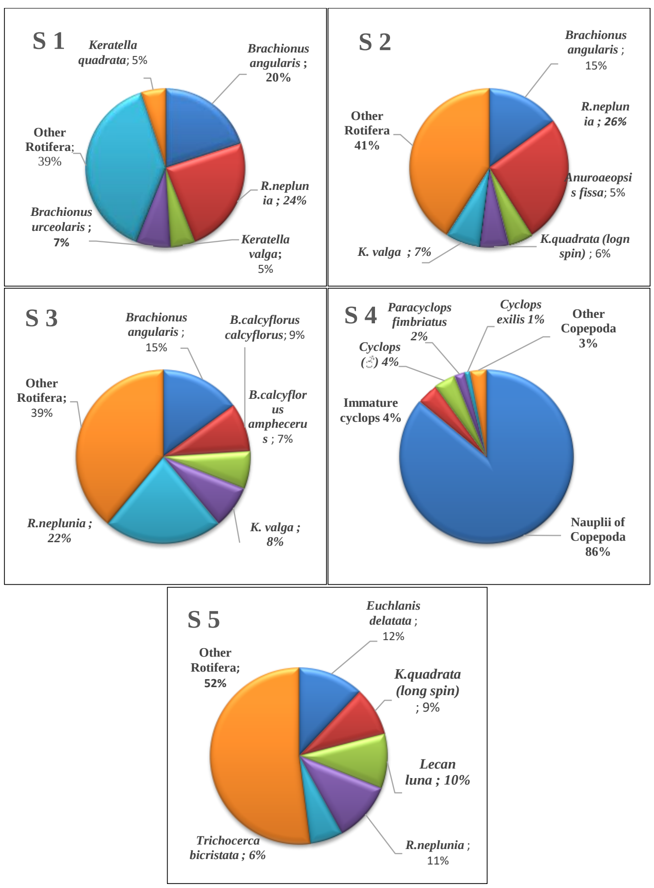

Figure 3. The most dominant rotifera species' relative abundance.

When compared to the total of other species present at site 4, *R. neplunia* recorded the highest proportion (17%), followed by *K. quadrata* with 13%, *B. angularis* with 9%, and *K. valga* with 5%.

Finally, at site 5, *Euchlanis delatata* had the highest percentage (12%) of the total density of other species, followed by *R. neptunia* and *Monostyla bull*, each with 11%, *Lecan luna*, 10%, and *K. quadrata* (long spin), 9%.

Throughout the study period, 67 taxonomic units of rotifera have been identified at all sites (Table 1). Our study's findings conflicted with some earlier research on the Tigris River, such as those by Rasheed *et al.* (2017) and Majeed *et al.* (2021), this could be for a number of reasons, such as the classification level, pore size plankton net, sample locations, and environmental circumstances.

The species richness index of rotifera throughout the study period was shown in Fig. (4). In site 1 during July, the highest values of the species richness index were 8.44, however, the lowest values were 3.92, which were reported in November at site 4.

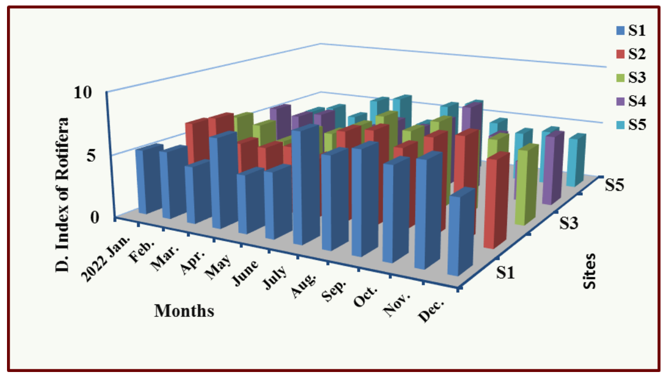

Figure 4. Monthly fluctuation of the Species Richness Index (D).

With regard to spatial variations, site1 has the highest value of the rotifera species richness index. While it was the lowest value in site 4. The recording high values for this indicator possibly result from a number of factors, including the existence of aquatic plants, which provides a suitable environment for the presence of coastal species attached to plants as well as the abundance of food along the course of the river contributed to the distribution of the rotifera community, depending on the principle of benefiting from the transported food (Beklyeen *et al.* 2011). As for the low values, it may be due to the fact that aquatic life is affected by pollution, which also alters the environment and how ecosystems function (Markert *et al.* 2004).

As for the temporal variations, rotifera recorded the highest values for the species richness index throughout the year, which may be due to the fact that the favorable conditions for species growth and abundance this also shows that the physical and chemical environmental factors are stable, together with the abundance of nutrients in the sea surface (Badsi *et al.* 2010).

According to Hussain, (2014) who divided the species richness index value into three categories. The index value was categorized as perfect if it was greater than 5, moderate if it was between 3 and 5, and disturbed if it was less than 2.5.

The current study's findings made it clear that the study locations' species richness indices ranged from perfect to moderate for the total number of rotifera. In general, we can observe that the species richness index varied across spatially and temporally in accordance with the local environmental conditions.

The Shannon-Wiener index values for rotifera during the study's period were shown in Fig. (5). The greatest values were 2.69 bit./Ind. in September at sites 2 and 3, and the lowest was 1.57 bit./Ind. in June at site 1.

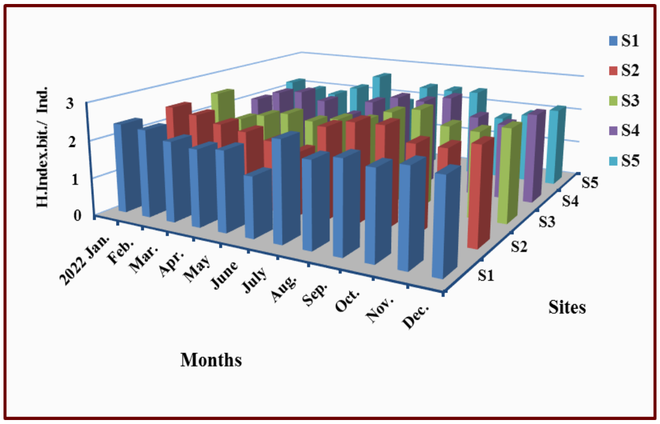

Figure 5. Monthly fluctuation of Shannon-Winner Diversity Index (H) bit./Ind.

As for spatial variation, site 3 obtained the highest Shannon-Winner biodiversity index values, while site1 had the lowest values. The increased dissolved oxygen, transparency, and flora density that serves as a food supply may be the cause of the site 3 higher values that were observed (Jase and Sanalkumar, 2012), while its decrease in site 1 may be due to the high amount of salts in this site, which reduces the diversity of rotifera (Czerniawski and Slugocki, 2017).

In regard to temporal fluctuation, the summer and autumn seasons had the highest values of the rotifera diversity index. This may be related to a suitable temperature, a high level of water transparency, and the presence of Chlorophy II, and these factors are necessary to provide phytoplankton which is food for zooplankton (Sharmila Sree and Shameem, 2017). While the decline might be caused on by an increase in turbidity and suspended matter, which has an impact on the variety of rotifera (Abdul Wahab and Rabee, 2015).

According to the study of Goel, (2008) and Hussain, (2014), they divided this index values as follows: Water that has a rate of more than 3 bit./Ind. is deemed clean.Water that is 1-3 bit./Ind. is regarded as moderately polluted.Water in less than 1 bit./Ind. is heavy polluted. According to the findings of the Shannon-Winner Diversity Index study, the Tigris River's water is heavy degrees of polluted.

The values for the Species Uniformity Index are shown in Fig. (6). In site 5, the maximum value of 0.88 was noted in September. and the minimum value was 0.44 in site 4 during May.

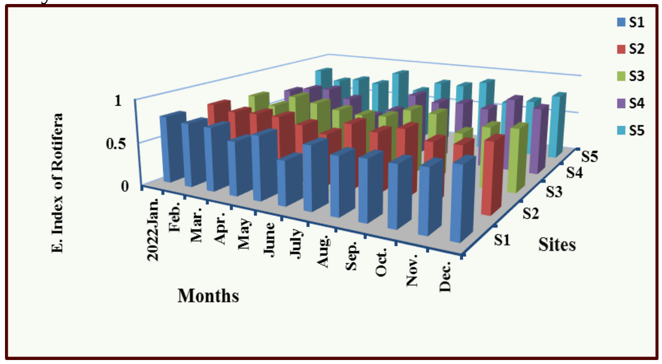

Figure 6. Monthly fluctuation of the Species Uniformity Index (E).

Regarding spatial fluctuation, site 5 recorded the greatest value of this index in September, equal to 0.88, while site 5 recorded the lowest values equal to 0.44, in May. This might be caused by variations in the physical, chemical, and hydrological factors between the sites, including: - water discharge, temperature, oxygen, turbidity, and salinity, this could impact the Species Uniformity values (Wu *et al.* 2017; Kamboj and Kamboj, 2020).

Regarding the temporal fluctuation, the highest value was observed during autumn, while the lowest value was observed during the summer. Since certain values approached 0.5 over the majority of the study period the high values of this index show that there is no environmental pressure, providing a suitable habitat for the stability of rotifera species in the Tigris River. As a result, the species' appearance is homogeneous (Smith and Knap, 2003).

Hussain, (2014) categorized as highly balanced if the species uniformity index values are between 0.9 and 0.8, moderately balanced if the values are between 0.6 and 0.7, and unbalanced if the values are below 5. Therefore, the rotifera Species Uniformity index classifies from unbalanced to highly balanced.

Table (2) and Fig. (7) show the Jaccard's presence coefficient matrix and dendrogram of Jaccard Index percentages of rotifera among all the studied sites. The rotifer similarity index obtained its greatest values between sites 2 and 3, reaching 72.82%. This may be due to the characteristics, water quality and the quality and abundance of aquatic plant, as they are open areas and devoid of the presence of industries on their banks. The lowest rotifera similarity index values, however, were between sites 1 and 4, where they reached 39.54%. (Table 2 and Fig. 7). This could be as a result of the presence of pollutants as well as the variability of water's physical and chemical characteristics, such as: water discharge rate, turbidity, electrical conductivity, total suspended solid, total hardness, bicarbonate, nitrates, phosphates and Chemical Oxygen Demands, which could be

seen in the presence of different species and how they interacted.

Table 2. Matrix of the presence coefficients of Jaccard between sites.

Step	Clusters	Distance	Similarity	Joined 1	Joined 2
1	4	17.27	82.73	2	3
2	3	17.50	82.50	1	2
3	2	46.58	53.42	4	5
4	1	60.43	39.57	1	4

Similarity Matrix Rotifera

	S 1	S 2	S 3	S 4	S 5
S 1	*	82.50	75.88	36.70	20.16
S 2	*	*	82.73	39.15	23.73
S 3	*	*	*	39.57	23.04
S 4	*	*	*	*	53.42
S 5	*	*	*	*	*

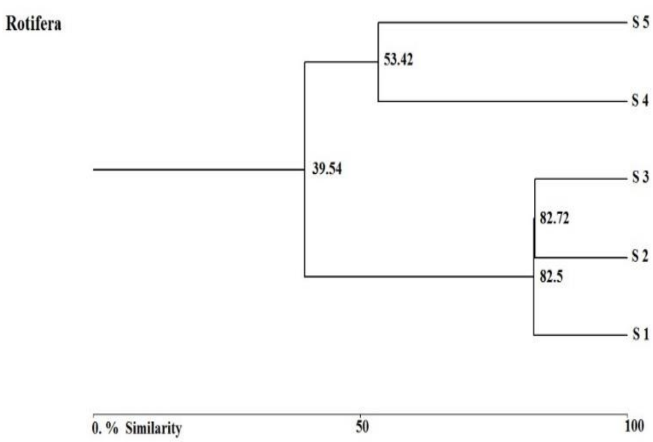

Figure 7. Dendrogram of Jaccard Index percentages of rotifer.

The strong similarity between the sites may result from the similarity in most of the water physico-chemical characteristics and zooplankton's environment's characteristics, while the decrease in the Jacquard index values and the distance of some sites may be due to the absence of some species that may exist when appropriate conditions are available. Thus, it differs from other sites, as the Jacquard index indicates the extent of similarity between societies depending on the composition of societies, and this guide is used to compare societies as well as to compare changes in the composition of society over time (Apaydin, 2013).

According to the Constancy index, it was recorded 34 taxonomic units were the most constant species during the study period which are:- *Anuroaeopsis fissa*, *Asplanecna priodonta*, *Brachionus angularis*, *B.calcyflorus calcyflorus*, *B.calcyflorus amphecerus*(long spin), *B.calcyflorus amphecerus*(short spin), *B.calcyflorus amphecerus*(long spin), *B. havanaensis*, *Brachionus falcatus*, *B.foricula B.quadridentatus*, *B.plicatlus*, *Brachionus urceolaris*, *Brachionus* sp., *Cephalodella aureculata*, *Cephalodella gibba*, *Colurella adriatica*, *Epiphanus macroura*, *Euchlanis delatata*, *Fillina longisetea*, *Keratella cochlearis*, *K.tropica*, *K.quadrata*(logn spin), *K.quadrata*(short spin), *K.valga*, *Lecan luna*, *Monostyla bulla*, *Mytilina mucronata*, *Patulus Platyias*, *Polyarthra dolicoptera*, *P.vulgaris*, *Rotaria neplunia*, *Syncheta oblonga* and *Testudinella patina*, and other taxa included accidental and accessory species(Table 1). Also, the results of the constancy index showed 27 constant taxonomic units was recorded in each of sites 1 and 2 which decreased to 24 constant taxonomic units at site 3. These taxonomic units reappeared to 14 and 16 constant taxonomic units recorded at sites 4 and 5, respectively.

The presence and reappearance of some species over the period study and at all sites and may be due to these species suffer greatly from changes in a wide range of environmental conditions, including nutrients, temperature, transparency, turbidity, and salinity (Kassim *et al.* 2006). Or the constant of some species may be due to their lack of food specialization and their method of reproduction, especially parthenogenesis and their high fertility (Jase and Sanalkumar, 2012).

***Conclusion*:** This study highlights the significant spatial and temporal variations in rotifer biodiversity in the upper sector of the Tigris River. The findings underscore the influence of environmental factors such as salinity, oxygen saturation, and phytoplankton density on rotifer populations. The high biodiversity and well-balanced ecosystem indicate the Tigris River's capacity to support diverse aquatic life. These insights can inform conservation strategies and water management practices to maintain and enhance the river's ecological health.

***Authors contributions statement*:** Muhanned R. Nashaat: Conceived the idea, designed the study and reviewed the manuscript; Shaima J. H. Idrees: Collected the data and wrote the manuscript; Jameel S. AL-Sariy: Assisted in reviewing and editing the manuscript; Muhanned R. Nashaat : Assisted in proofreading; Shaima J. H. Idrees was encouraged by Muhanned R. Nashaat and Jameel S. AL-Sariy to research [a specific aspect], and these two men oversaw the research's results. Each author contributed to the final manuscript and discussed the findings.

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